Egyptian Journal of Chest Diseases and Tuberculosis (2012) **61**, 323–328

EJCT

The Egyptian Society of Chest Diseases and Tuberculosis

Egyptian Journal of Chest Diseases and Tuberculosis

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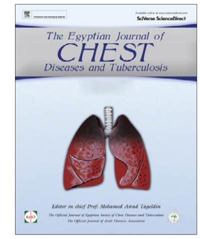

ORIGINAL ARTICLE

The role of impulse oscillometry in assessment of airway obstruction in smokers and ex-smokers

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Received 10 August 2012; accepted 22 August 2012
Available online 24 January 2013

KEYWORDS
Impulse oscillometry;
Spirometry;
Smoking

Abstract *Background:* Impulse oscillometry provides useful clinical information that prominently includes functional assessment of small, peripheral airway behavior beyond that available from commonly used pulmonary function tests (PFT). The aim of this study was to assess the role of impulse oscillometry in assessment of airway obstruction in smokers and ex-smokers.

Methods: Sixty subjects divided into three groups (asymptomatic smokers, ex-smokers and non smoker healthy subjects as a controls) all were assessed by spirometry and IOS.

Results: Based on the IOS results in smokers, there was 17 negative cases and only 3 diseased cases, the calculated Specificity of spirometry (ability to detect negative cases as negative) 100%, while its sensitivity (ability to detect diseased cases as diseased) was only 33% as it was able to detect one diseased case from a total of three cases .In ex-smokers, there was 13 negative cases and only 7 diseased cases, the calculated Specificity of spirometry (ability to detect negative cases as negative) 100%, while its sensitivity (ability to detect diseased cases as diseased) was only 42.8% as it was able to detect 3 diseased case from a total of 7 cases. In controls, there was 18 negative cases and two diseased cases, the calculated Specificity of spirometry (ability to detect negative cases as negative) 100%, while its sensitivity (ability to detect diseased cases as diseased) was 50% as it was able to detect 1 diseased case from a total of 2 cases.

Conclusion: IOS is an effective, easy to perform, and a non invasive method for the assessment of airway obstruction in obstructive pulmonary disorders. Although, there is no significant difference between impulse oscillometry and spirometry parameters in early detection of airway obstruction in smokers and ex-smokers groups.

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Peer review under responsibility of The Egyptian Society of Chest Diseases and Tuberculosis.

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Introduction

Smoking is the main cause of COPD. If a person has never smoked, it would be very unlikely that he would develop COPD. Most sufferers of COPD are smokers or used to be smokers and between 80% and 90% of all deaths from COPD are due to smoking. Cigarette smoking is known to be

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associated with chronic bronchitis, centrilobular emphysema, increase sputum production, decrease ciliary activity, macrophage function, bronchial epithelium changes, and mucus gland enlargement. Such conditions combine to cause disease of the small airways, which considered to be the “silent predecessor” to cause COPD. Early detection is of significant value because smoking stops and treatment begin, the disease process may be reversible and pulmonary function can improve. Because the pulmonary system has large reserve capacity, significant changes in function greatly occur before symptoms of respiratory disease are apparent [1].

There is a need for a reliable, easy to perform, screening test for these disorders. The conventional pulmonary function test (cPFT) of spirometry, and body plethysmography, are largely subject-dependent. They require maximal individual effort through forced expiratory maneuver. To overcome these difficulties, measurement of expiratory impedance (Zrs), first introduced in 1967 requires minimal patient effort through forced oscillation technique (FOT). The basic principle of FOT is to measure the relation between pressure waves applied externally to the respiratory system, and the resulting respiratory airflow. The ratio of the amplitude of pressure wave to amplitude of resulting flow wave constitutes the impedance of the respiratory system (Zrs). The basic indices obtained by oscillation technique are the two components of respiratory impedance: total respiratory resistance (Ras) and reactance (Xrs) [2].

The measurement of respiratory impedance should be considered whenever spirometry cannot be performed or appears to be unreliable. These qualities of the forced oscillation technique make it an ideal tool to study airway patency during sleep or to monitor the respiratory properties during mechanical ventilation. Additionally, the small amplitude oscillation do not influence the respiratory mechanical properties studied, and this is particularly important when assessing bronchoactive responses [3].

The aim of the work is to study the role of impulse oscillometry in assessment of airway obstruction in smoker and ex-smoker.

Materials and methods

Subjects: This study was carried out on sixty subjects came to the outpatient clinic of Ain Shams University Hospital.

Subjects were classified into three groups as follows:

Group A: twenty asymptomatic smokers, Group B: twenty ex-smokers, Group C: twenty healthy non-smoker subjects serving as control group.

The following subjects were excluded from the study: patients with chronic chest disease or any systemic disease affecting the chest.

Informed consent was obtained and the protocol of the study was approved by ethical committee of the Faculty of Medicine, Ain Shams University.

All were subjected to full medical history and chest X-ray and thorough clinical examination.

Lung Function:

FEV1, FVC, FEV1/FVC, and maximum mid-expiratory flow (MMEF) were measured using the Spirometry system (Masterscreen 2001, version 4.5, Erich Jaeger GMBH, Germany). Readings were preformed in triplicate, with the highest values recorded and expressed as a percentage of the predicted value. The following activities were avoided prior to Spirometric study according to the guidelines of American Thoracic Society/European thoracic society, 2005 [4]:

1. Smoking within at least 1 h of testing.
2. Performing vigorous exercise within 30 min of testing.
3. Wearing clothes that substantially restrict full chest and abdominal expansion.
4. Eating a large meal within 2 h of testing.
5. Taking long acting bronchodilator for 12 h or short acting bronchodilator for 6 h.

Diagnosis of airway obstruction by Spirometry and IOS:
Spirometry [5]:
Obstructive pattern is identified by:

1. FEV1 below 80% predicted.
2. FVC can be normal or reduced (usually to a lesser degree than FEV1).
3. FEV1/FVC ratio below 0.7

IOS: The IOS measurement was performed using Master lab-IOS unit (Masterscreen IOS 2001, version 4.5, Erich Jaeger GmbH, Germany) according to the main principles of the European Respiratory Society (ERS) Task Force recommendations [3]. The actual values of respiratory resistance at 5 and 20 Hz (R5 and R20, respectively), and distal capacitive reactance at 5 Hz (X5) were recorded [2].

Proximal obstruction

Total respiratory resistance R5 is higher than 150% predicted R5, and within abnormal range.

The resistance spectrum R(f) is independent of frequency and almost horizontal i.e., proximal respiratory resistance R20 is similar to total respiratory resistance R5.

Distal capacitive reactance X5 is completely within the normal range, as the resonant frequency.

Peripheral obstruction

1. The R5 is within abnormal range i.e. >150% predicted, and the R20 is considerably lower than R5.
2. The R(f) is frequency dependent becoming less at higher frequencies.
3. The X5 is reduced into the abnormal range, and the fres is shifted to the right (to higher frequencies).

Statistical analysis

The collected data was revised, coded, tabulated and introduced to a PC using Statistical package for Social Science (SPSS 15.0.1 for windows; SPSS Inc., Chicago, IL, 2001). Data was presented and suitable analysis was done according to the type of data obtained for each parameter.

i. *Descriptive statistics:*

1. Mean.
2. Standard deviation (±SD).
3. Minimum and maximum values (range) for numerical data.

Frequency and percentage of non-numerical data.

i. *Analytical statistics:*

1. *Independent-Samples T* Test was used to assess the statistical significance of the difference between two study group means.
2. *ANOVA test* was used to assess the statistical significance of the difference between more than two study group means.
3. *Correlation analysis (using Pearson's method):* To assess the strength of association between two quantitative variables. The correlation coefficient denoted symbolically "*r*" defines the strength and direction of the linear relationship between two variables.
4. *Chi-Square test* was used to examine the relationship between two qualitative variables.
   P-value: level of significance
   $P > 0.05$: Non significant (NS).
   $P < 0.05$: Significant (S).
   $P < 0.01$: Highly significant (HS).

Results

Sixty subjects divided into three groups: asymptomatic smokers, ex-smokers and non-smokers as control group. All recruited from the outpatient clinics at Ain Shams University hospital. All the subjects were males in the smokers and the ex-smokers groups, among the smokers group the mean age was 35.28 + 9 years, and among the ex-smokers group the mean age was 42.11 + 8.6 and among the control group included 17 males and 3 females with a mean age 29.5 + 4 (Tables 1–7).

Discussion

Smoking may cause diseases through a myriad of mechanisms; cigarette smoke contains more than 6000 compounds. Detailed toxicity studies have been done on relatively few of the

Table 1 Descriptive statistics.

Characteristics	Asymptomatic smokers	Ex-smokers	Non-smokers
Age	35.28 ± 9.093	42.11 ± 8.615	29.20 ± 4.26
Pack/year	28.61 ± 12.10	35.83 ± 9.27	–
FEV1 of pred.	96.68 ± 12.48	89.13 ± 8.16	93.080 ± 7.24
FEV1/FVC%	98.3 ± 10.32	88.34 ± 9.57	83.79 ± 8.32
R5 Hz	120.88 ± 40.24	155.41 ± 39.26	132.77 ± 28.80
R20 Hz	108.6 ± 41.29	136.21 ± 36.97	123.68 ± 32.45

FEV1(%), forced expiratory volume in one second percent predicted; FVC%, forced vital capacity, R5(%), total respiratory resistance percent predicted; R20(%), proximal respiratory resistance percent predicted.

Table 2 Comparison between IOS diagnosis and spirometry diagnosis in smokers.

			IOS diagnosis		Total
			Non-obstructive	Obstructive	
Diagnosis by spirometry	Non-obstructive	Count	17	2	19
		% within IOS	100.0%	66.7%	95%
	Obstructive	Count	0	1	1
		% within IOS	0%	33.3%	5%
Total		Count	17	3	20
		% within IOS	100.0%	100.0%	100.0%

Table 3 Comparison between IOS diagnosis and spirometry diagnosis in ex-smokers.

			IOS		Total
			Non-obstructive	Obstructive	
PFT	Non-obstructive	Count	13	4	17
		% within IOS	100%	100.0%	85%
	Obstructive	Count	0	3	3
		% within IOS	0%	42.8%	15%
Total		Count	13	7	20
		% within IOS	100.0%	100.0%	100.0%

Table 4 Comparison between IOS diagnosis and spirometry diagnosis in controls.

			IOS		Total
			Non-obstructive	Obstructive	
PFT	Non-obstructive	Count	18	1	19
		% within IOS	100%	50.0%	95%
	Obstructive	Count	0	1	1
		% within IOS	22.2%	50.0%	5%
Total		Count	18	2	20
		% within IOS	100.0%	100.0%	100.0%

Table 5 Comparison between smokers and ex-smokers regarding IOS diagnosis.

			Type		Total
			Smoker	Ex-smoker	
IOS	Non-obstructive	Count	17	13	30
		% within Type	85%	65%	75%
	Obstructive	Count	3	7	10
		% within Type	15%	35%	25%
Total		Count	20	20	40
		% within Type	100.0%	100.0%	100.0%

Chi-Square = 2.215, *P*-value = .137, $P > 0.05$, NS.

Table 6 Comparison between smokers and ex-smokers regarding spirometry diagnosis.

			Type		Total
			smoker	Ex-smoker	
PFT	Non-obstructive	Count	19	17	36
		% within Type	95%	95%	90%
	Obstructive	Count	1	3	4
		% within Type	5%	15%	10%
Total		Count	20	20	40
		% within Type	100.0%	100.0%	100.0%

Chi-Square = 0, *P*-value = 1, $P > 0.05$, NS.

Table 7 Correlations between X5 Hz and other spirometry and IOS parameters in all groups.

		FEV1	FEV1/FVC	R5 Hz	R20 Hz
X5 Hz	*r*	.105	.314	−.195	−.118
	P-value	.447	.020	.154	.391
	Sig.	NS	S	NS	NS
	N	60	60	60	60

FEV1(%), forced expiratory volume in one second percent predicted; FVC%, forced vital capacity, R5(%), total respiratory resistance percent predicted; R20(%), proximal respiratory resistance percent predicted, X5 distal capacitive reactance.

potential toxins. Some toxins are present in tobacco plant; others are generated during tobacco leaf processing or pyrolysis of processed tobacco. Tobacco smoke contains compounds that can disrupt DNA, causing mutations and altering gene expression. In addition compounds may bind to and disrupt proteins and alter cellular lipids. Because of the diversity of the toxins, the many biochemical and cellular elements with which they may interact and the variability in individual susceptibilities, the heterogeneous ill effects of cigarette smoke are not surprising. Among the most prevalent diseases with which cigarette smoking has been implicated are atherosclerotic cardiovascular diseases, cancer and chronic obstructive pulmonary disease [6].

Pulmonary function tests are a group of laboratory tests used for evaluating the respiratory functions of the respiratory system to assess the physical fitness and working ability of individuals [5].

Spirometry is a physiological test that measures how an individual inhales or exhales volumes of air as a function of time. The primary signal measured in spirometry may be volume or flow, it is capable of measuring all lung volumes and capacities except RV, FRC, and TLC [5].

Impulse Oscillation technique is a technique modified and computerized in a way that allows measurement of respiratory impedance, total respiratory resistance and reactance components over a range of oscillating frequencies within seconds, with simple tidal breathing [2].

Impulse Oscillometry is a noninvasive and effort-independent test used to characterize the mechanical impedance of the respiratory system. The clinical potential of the impulse Oscillometry is rapid and demands only passive cooperation which makes it especially appealing for children, for epidemiologic surveys and for conditions in which quiet breathig instead of forced expiratory maneuvers are preferred [7].

The aim of this study was to assess the role of impulse oscillometry in assessment of airways obstruction in smokers and ex-smokers.

The present study was conducted on sixty subjects; twenty non smoker healthy subjects as a control group and twenty asymptomatic smokers and twenty ex-smokers were attending the Outpatient Clinics.

All subjects underwent spirometry and IOS.

Among the smokers group in the present study, all subjects were males with a mean age of 35.28 + 9 years, and among the ex-smokers group all subjects were males with a mean age of 42.11 + 8.6 and among the control group included 17 males and 3 females with a mean age 29.5 + 4.

Due to the unmatching of both age and sex among the three studied groups, there was a highly significant statistical difference between the studied groups as regards both age and sex.

Based on the IOS results in smokers, where there was 17 negative cases and only 3 diseased cases, the calculated Specificity of spirometry (ability to detect negative cases as negative) 100%, while its sensitivity (ability to detect diseased cases as diseased) was only 33% as it was able to detect one diseased case from a total of three cases.

Based on the IOS results in ex-smokers, where there was 13 negative cases and only 7 diseased cases, the calculated Specificity of spirometry (ability to detect negative cases as negative) 100%, while its sensitivity (ability to detect diseased cases as diseased) was only 42.8% as it was able to detect 3 diseased case from a total of 7 cases.

Based on the IOS results in controls where there was 18 negative cases and only one diseased cases, the calculated Specificity of spirometry (ability to detect negative cases as negative) 100%, while its sensitivity (ability to detect diseased cases as diseased) was 50% as it was able to detect 1 diseased case from a total of 2 cases.

In the present study the parameters of spirometry and impulse oscillometry were not statistically significantly differences between non-smoking group and smoking group this was matching with the study done by Kim et al., the objective of his study is to evaluate the clinical ability of impulse oscillometry to detect about smoking induced early airway obstruction in 108 persons with normal spirometry test. Respiratory asymptomatic study groups were formed that one is non-smoking group, another is smoking group. [7].

In the present study total resistance (non-smoking group:smoking group = 132.77 + 28.8:120.88 + 42.24) that was not statistically significantly differences and this matched with the study done by Kim et al. [7].

Also central resistance and lung compliance were not statistically significantly different between non-smoking group and smoking group in the present study and this was matching with the study done by Kim et al. [7].

In the present study there is no significant correlation between FEV1% pred and R5% pred, and this was not matching with the study done by Jiang et al. [8], the objective of his study is to explore the application of impulse oscillometry (IOS) in the estimation of airway obstruction and to evaluate the correlation between spirometry indices and IOS parameters. Spirometry and IOS measurements were performed in 100 participants (male 72, female 28). FEV1% of pred, FVC, FEV(1)/FVC%, airway resistance at 5 Hz (R5), airway resistance at 20 Hz (R20), central resistance (Rc) and peripheral resistance (Rp) of structural parameters interpretation graph, FEV1% of pred, R5% pred, R20% pred, and FEV1/FVC% were analyzed. Correlations between spirometry and IOS parameters were studied, and there was significant negative correlation between FEV(1)% pred and R(5)% pred .This could be attributed to small number of subjects included in the present study as it was performed only on 60 subjects [8].

In this study and Based on the IOS results in asymptomatic smokers group, where there are 17 negative cases and only 3 diseased cases, the calculated sensitivity (ability to detect diseased cases as diseased) was only 33%, as it was able to detect one diseased case from a total of three cases, while its sensitivity in ex-smoker was only 42.8%, as it was able to detect 3 diseased case from a total of 7 cases, and its sensitivity in control group was 50% as it was able to detect 1 diseased case from a total of 2 cases, so spirometry sensitivity in all groups in the present study was 41.67% as it was able to detect 5 diseased case from a total of 12 cases, this is matched with the study done by Al-Mutairi et al. [2]. The objective of his study is to assess the use of impulse oscillometry as an alternative modality to the conventional pulmonary function test (cPFT) to test lung mechanics. As the sensitivity of spirometry to detect obstructive airway diseases was 47.4% [2].

From the present study it was found that there is no significant different between impulse oscillometry and spirometry parameter in early detection of airway obstruction in smokers and ex-smokers groups.

Finally, IOS is an effective, easy to perform, and a non invasive method for the assessment of airway obstruction in obstructive pulmonary disorders.

There is no significant difference between impulse oscillometry and spirometry parameter in early detection of airway obstruction in smokers and ex-smokers groups.

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